

Semi-Annual Progress Report

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Task Objectives

The objectives of the last six months were:

Review and comment on proposed changes to the MODIS sensor specifications

Review and revise the MODIS Data Products list

Review and comment on the Team Leader Compute Facility plan and various Project software plans

Continue development of local Scientific Compute Facility

Continue development of local Software Development plan

Prepare white paper on ocean color measurements

Complete analysis of sun-stimulated fluorescence data collected off northern California and prepare for 1993 field work

Hire an information systems developer

Work Accomplished

Sensor Performance Requirements

Continued requests were made by the project to review proposed changes to the specifications for MODIS (formerly known as MODIS-N). I participated in these activities at the MODIS team meeting in October. No major changes were proposed that affected ocean color bands.

Project Data and Information System Plans

Data Products List

As part of the NASA Red Team/Blue Team activities, the program has proposed a much reduced data product list for MODIS.

Although the focus was on only products that could be produced at launch, there were numerous products that could easily be produced and in fact, should be produced. In some

cases, this included "intermediate" products that are made in the process of producing some geophysical quantity. Examples include information on atmospheric aerosols that are used in atmospheric correction. In other cases, valuable data sets were left off the list.

I proposed that NASA establish a more formal process and review of these data products that would review every data product, including those proposed by NASA Headquarters. This must be a joint process between the EOS Investigators Working Group as well as those responsible for producing data products.

We need to take a new approach, rather than try to clean up a flawed system. We should first identify the critical data products (by sensor) without regard to temporal or spatial resolution. The criteria for "critical data product" should include an assessment of the science need for the product, its heritage, and its "reasonableness." We should not focus only on products that are ready to run at launch. I think is short-sighted; there will be little incentive to develop new, more complicated products with this approach. In fact, the whole product list process, has alternately swung between these two extremes of too conservative and too expansive. I think we need to strike a balance between these two. I also think some level of redundancy is not bad, such as multiple estimates of incident photosynthetically available radiation (PAR). Investigators often use different approaches, even with the same sensor data set. Making a priori choices as to which is the best approach is not prudent.

In terms of MODIS, I suggested the following changes to the HQ list:

Chlorophyll fluorescence efficiency (3211/3212) is the ratio of fluorescence to the chlorophyll concentration (as derived from other MODIS channels). The efficiency can be used in models of primary productivity or in estimating the light response of phytoplankton, one of the primary variables in carbon fixation.

Chlorophyll via fluorescence (2566/2567) is a straightforward product derived from fluorescence line height. Although the radiance ratio method is the primary approach for global chlorophyll estimates, fluorescence will be superior in regions of high chlorophyll and turbid, coastal waters.

Ocean water attenuation (2031/2032, 3199/3200, and 3206/3207) is necessary for models of mixed layer depth and primary productivity. These models are well-developed.

Suspended solids concentration (3085/3086) is also important in estimating riverine fluxes of material into the coastal ocean.

Products related to coccolith concentration (2577/2578 and perhaps 2556/2557) should be retained. The enhanced backscatter from coccoliths must be accounted for in the bio-optical algorithms used to derive a range of other ocean products such as pigment and productivity. More importantly, coccolithophores are the primary producers of DMS in the ocean, which is important for cloud formation.

Pigment concentration (2591/2591) is the combination of chlorophyll plus associated degradation products. It should be retained for continuity with the CZCS, SeaWiFS, and EOS-Color data sets. These latter sensors are less sensitive and are not able to distinguish chlorophyll from the degradation products (unlike MODIS).

Phytoplankton backscatter coefficient (2555/2558) will be useful for distinguishing the types of phytoplankton in the upper ocean. As various types have different photosynthetic characteristics, these data should improve our productivity estimates. Similar estimates

should be possible from SeaWiFS so there is heritage for these products.

The atmosphere products (2295/2296 and 2344/2345) are essential intermediate products that are used for data validation and quality checking.

There are several instrument-related data products that should also be retained. These include the instrument characterization and calibration products to be developed by Salomonson and Barker. The data masks (3660/3661 and 2282/2283/2284) must be retained so that subsequent processing focuses on the regions of interest (i.e., fluorescence is calculated for ocean pixels, not cloud or land).

Team Leader Compute Facility and Software Development Plan

A revised version of the Team Leader Compute Facility plan was distributed for review. I provided comments on this plan to Al Fleig. In general the plan was reasonable, but I am concerned about the lack of attention towards networking and intra-team communications. Considerable effort must be placed on the development of an infrastructure that supports close collaboration between team members as well as between individual team members and the Project.

I also provided comments as request on the Science Data Management Plan developed by the project. As with the Team Leader Compute Facility report, the SDMP was in good shape, at least those sections that were complete. However, a number of difficult management issues remain. For example, the whole area of reprocessing as well as delegation of responsibility for updates to processing algorithms and operating systems has not been addressed.

Product Generation Toolkit

Many of the proposed libraries will be useful but the proposal to build a complete firewall between code and machine/OS as the cure-all for machine portability is not realistic. The idea that with the "right" libraries, all machine and operating system quirks can be dealt with while still not crippling the language will not work. Many system dependencies cannot be masked by libraries. Machine characteristics such as word length, byte order, vector hardware, floating point formats, etc. can be all too visible to the programmer (especially in C). Operating systems have an equally wide variety of file types, interprocess communication methods, system limits, exception handling, "magic" files, etc. How much of this should be hidden? How much should be kept at any cost (including writing emulation routines on non-endowed machines)? How much is really needed to get the job of EOS product generation done?

There are, of course, drawbacks common to any attempt to place a wrapper around an existing library. First, you lose the familiarity programmers had with the existing library, forcing everyone up the learning curve again. And second, there are many new sources for bugs (is the bug in the OS, the wrapper code, or my use of this unfamiliar library?). And third, Unix is big, very big. It is not possible to reimplement stdio, libm, etc. just for aesthetics. Big companies with thousands of users to report bugs have a very difficult time tracking down all the errors. And this is for a system that has been around in one form or another for 15 or so years. The PGS libraries are likely to have similar growing pains.

If the PGS Toolkit report is taken literally, then all I/O functions will be replaced by PGS substitutes. This will eliminate write() from C and WRITE from FORTRAN. But will the designers choose to implement analogs of printf(), fprintf(), sprintf(), putc(), putchar(), fwrite(), etc. Or will time and budget constraints force me to use the subset of routines that

the library implementors thought I needed? What about strings, shared memory, exception handling, variable arguments, sockets, asynchronous I/O, etc? What about any tuning effort that went into the vendor libraries, will that be lost as well?

The idea does have some merit, however. The idea of transparently locating and staging data without having to know the network and archive structure would be very useful. Similarly, the routines for geographic coordinate conversion, celestial body location, math and statistics, etc. would all be very useful.

Local Scientific Compute Facilities

I provided my 10-year plan to Al Fleig for the acquisition of my local SCF. The plan is unchanged from that reported in the last semi-annual report. The core compute machines (CM-5 and CM-200 from Thinking Machines and an IBM cluster will be linked via a high-speed fabric, likely Fiber Channel Standard (FCS). This core will be attached via a high speed router to our visualization, data base, and file servers. Through the router, information will flow to various desktop machines. The bulk of this equipment is being provided from NASA through my EOS interdisciplinary grant.

This team member compute facility will be used to support two activities: algorithm development and validation, and quality monitoring as MODIS data become available. The SCF at OSU will be part of the overall MODIS Ocean Compute Facility, coordinated by team members at the University of Miami. This SCF must support many functions. First, it must provide a controlled environment for software development and testing, presumably using tools provided by EOSDIS. Second, it must provide sufficient data storage and management capabilities to store large amounts of pre-EOS and EOS data sets. Third, it must provide analysis and visualization capabilities that are adequate for the large volumes of EOS and non-EOS data. Fourth, there must be adequate networking capabilities to provide sufficient bandwidth and connectivity between the OSU SCF, the EOSDIS Science Network (ESN), and other MODIS team members. Fifth, the system must provide sufficient administrative functions necessary to support the documentation, reporting, and financial management needs of the MODIS contract.

The OSU SCF will be coordinated with the larger SCF provided under EOS interdisciplinary SCF support provided by NASA Headquarters. Although the interdisciplinary SCF is focused primarily on data analysis and numerical modeling, it must manage and process large amounts of data as well. The two activities are complementary, and we will coordinate the purchases where appropriate.

In 1993, our activities will focus on analysis of sun-stimulated fluorescence data that will be collected by Lagrangian drifters (supported by the Office of Naval Research), advanced algorithm development in support of SeaWiFS (in collaboration with the University of Miami), and on new methods of data visualization and analysis. The data analysis will be conducted on Sun-class UNIX workstations with sufficient memory and disk. The next generation of ocean color sensors (as represented by SeaWiFS) will require more complex atmospheric correction algorithms. These new algorithms will need more compute power; it appears that a massively parallel implementation will be needed. We will work with the Miami team to port their models to the Thinking Machines CM-5 at OSU. This activity will require a T3 line between Miami and OSU to provide sufficient bandwidth for data transport and real-time visualization. We plan to integrate a visualization package with this algorithm so that we can explore the complex parameter space associated with it. Lastly, we will begin software development to provide links between data management and analysis/visualization, probably using object-oriented methods.

In 1994, SeaWiFS data will become available. Our present Silicon Graphics workstation will be upgraded with additional processors to accommodate these new data for analysis. This SGI machine supports both processing and visualization; in 1995 a new machine will be acquired to support visualization, thus freeing the existing SGI for processing. This visualization machine will require appropriate software, memory, and disk space to accommodate these CPU-intensive tasks. Memory and disk will be added to the SGI processing machine as well. Lastly, a print server will be added in 1995 to support document production.

Between now and 1995, the interdisciplinary SCF and the MODIS SCF will be connected via ethernet. With the increasing volume of data in 1996 from both SeaWiFS and OCTS, it will be necessary to link these two systems via higher speed networks, probably Fiber Channel Standard (FCS). We will purchase appropriate networking equipment in 1996 as well as upgrades to the existing machines to connect to this new network. We will also increase the amount of available storage by acquiring more disk drives and an optical disk jukebox. A visualization workstation will be added for new staff.

Storage will continue to be increased in 1997, but this will now be supported by a dedicated file server. This server will run a Unitree-like hierarchical storage management system that will be coupled with a data management system. Further improvements to the network will also be made in 1997. These improvements will likely include SONET/ATM to the desktop machines. As the CM-5 will be approaching the end of its useful life, memory/CPU upgrade funds will be used to move to the next-generation SGI data processing system. We point out that it is not possible to specify the exact capabilities of this machine, but it should be in 1 GFlop range, given advances in CPU design. Lastly, our existing video recording equipment will need to be replaced in 1997 as well.

With the launch of EOS in 1998, it will be necessary to combine the interdisciplinary SCF funds with MODIS SCF funds to take the Thinking Machines CM-5 to the next-generation massively parallel machine. This acquisition will also require a new storage subsystem. In addition, a CD-ROM jukebox will be needed as it is likely this will be the preferred distribution method for MODIS data. Desktop workstations will also be needed for new staff.

Data management will require a dedicated system in 1999. Storage and memory will be acquired as part of this system. The video recording equipment will be upgraded, as will several desktop workstations. Output devices (both b/w and color laser printers) will be needed to support publications and documentation.

In 2000, these processing, data management, and file server systems will be upgraded. Desktop workstations will also be upgraded or replaced. Networking equipment will also be upgraded as advances in communications technology continue. This upgrade process will continue into 2001.

Software Development and Data Plan

Bob Evans and I are continuing to work on the Software Development Plan for the MODIS Oceans Team. We expect that this will be completed in spring 1993. The general outline was presented in the previous semi-annual report.

Ocean Color White Paper

An ad hoc committee was formed in 1991 to report on ocean color research in the pre-EOS and EOS eras. The priorities for this research are:

Improve our quantitative understanding of the oceans role in the global carbon cycle. Specifically, ocean color imagery, in situ bio-optical measurements, numerical models and measurements from other space sensors (e.g. scatterometer) will be used to improve estimates of:

- the production and fate of particulate and dissolved organic carbon in the global ocean
- the effects of phytoplankton blooms on exchange rates of carbon dioxide between the atmosphere and the upper ocean

Improve our quantitative understanding of how light absorption by the upper ocean affects the ocean heat budget.

Improve our quantitative understanding of how phytoplankton blooms affect the production and air/sea exchange of DMS and other trace gases that may affect cloud formation and other atmospheric processes.

Provide the first quantitative estimates of interannual to decadal changes in global ocean primary production

Our long-term goal is to understand not only how ocean biological processes affect the global carbon cycle, but how they will change in response to changes in physical forcing. An understanding of the coupled dynamics of ocean biology, ocean physics, and atmospheric forcing is the ultimate objective.

Beginning in 1993, there should be nearly continuous ocean color measurements for the next 20 years. SeaWiFS will provide the first data set, beginning in 1993 with a planned 5-year mission. It will be followed by OCTS on ADEOS-1 (NASDA) in 1997 and by MODIS on the first EOS platform scheduled for 1998. A follow-on SeaWiFS-class sensor will also be launched in 1998 (EOS-Color) as will MERIS on POEM-1 (ESA). A second MODIS will be launched on the second EOS platform in 2000. After this point, there will be two copies of MODIS in orbit at any one time for the 15-year EOS mission.

The ad hoc committee proposed several implementation priorities to accomplish the science objectives, using the satellite missions as the basic observational framework. These priorities are:

- Two-day global coverage at 1-km resolution with a sensor meeting at least SeaWiFS-type technical specifications (continuous record)

- In-water measurements to validate water-leaving radiances and to evaluate regional Chl a algorithms

- Develop models of ocean productivity and its effects on air/sea carbon dioxide and trace gas exchanges, fates of organic carbon, and ocean heat budgets using satellite ocean color imagery, in situ data and derived products from other satellite sensors such as wind stress, sea surface temperature and solar insolation

- Acquire measurements centered near 412 nm for estimates of detrital carbon and improved estimates of Chl a in oceanic and coastal waters and at the sunlight-induced fluorescence band (ca. 685 nm) for improved estimates of coastal Chl a concentrations and for determining physiological state of phytoplankton (to improve estimates of primary production)

Full-spectral coverage from 400 nm through the near-IR (800 nm) to resolve accessory pigments and for refined estimates of Chl a, detrital carbon and other in-water constituents

These priorities serve well as an initial start for a research plan. However, there are some important modifications that should be made to cover the full suite of missions. First, global observations at 1 km spatial resolution on a daily basis will greatly improve our understanding of the role of mesoscale processes in the upper ocean. Given that eddy sizes in many parts of the ocean are of order 10 km, the initial SeaWiFS resolution of 4 km will not be adequate. Coupled with cloud patterns, it is clear that more frequent sampling will also be necessary to resolve the temporal variability of these features. Recent field and model studies have shown that variability on these scales may play a critical role in the coupling of atmosphere and the upper ocean. Second, improved sensor performance beyond SeaWiFS is essential to make the full spectral measurements as well as the fluorescence data. The original MODIS-T sensor met these specifications.

Given the context of nearly-continuous ocean color measurements and the long-range goal of understanding the coupled physical/biological system, there are several derived requirements for observations. First, the development of fully coupled ocean/atmosphere models that include both biological and physical processes will require a full suite of physical measurements concurrent with measurements of ocean biology. Second, an active program of cross-calibration between the sensors is essential if we are to develop a 20-year data record. This program must include some overlap period between the sensors and an active in situ calibration/validation program. Third, the data will be processed and archived by several groups so that access to the data and the corresponding algorithms must be ensured. These requirements will be challenging, given that the time series will be comprised of measurements from several different sensors from several different countries. Although these challenges are not insurmountable, planning must begin immediately if we are to achieve the fundamental goal of a consistent, 20-year record. Numerous examples exist, such as AVHRR and ACRIM, where such a consistent record could not be assembled even when the same sensors were used to collect the record.

In the context of a satellite ocean color program, field measurements should be focused on calibration and validation of the sensors as well as algorithm development. The SeaWiFS project has defined a suite of measurements and protocols that should serve as a baseline for future field programs. Sampling strategies should consist of both intensive, focused cruises, and extensive, less intense measurements from moorings and drifters.

Algorithm and model development will take place as part of PI-driven field programs, rather than as part of specific flight projects. The exception would be new algorithms designed to take advantage of new sensor capabilities, such as the 412 nm band for dissolved organic matter. In terms of model development, specific activities need to be directed towards characterizing the spatial and temporal variability of the critical variables of the models as well as of the model relationships. This characterization is essential if we are to construct models that can assimilate satellite data. Although this activity is beyond the scope of an instrument flight project, it must be conducted in a systematic manner and not just restricted to a few locales.

It is apparent that the field component of satellite missions must work in close cooperation with existing and planned field programs, especially those that have global focus such as JGOFS. NASA must work cooperatively with agencies that control ship funding and schedules to ensure that these vital field measurements are supported.

With the Coastal Zone Color Scanner, it was only possible to estimate total pigment concentrations as there was insufficient spectral resolution to separate chlorophyll *a* from its associated degradation products. Although this works reasonably well, several studies have shown that the bio-optical algorithms may fail in the presence of dissolved organic matter such as humic acids which occur even in the open ocean. SeaWiFS and follow-on sensors will have channels near 412 nm to measure the concentration of DOM. Although there remain challenges for atmospheric correction at these short wavelengths, the availability of these measurements may extend the range of water types that can be studied quantitatively from space.

Additional wavelengths and increased sensitivity will also allow chlorophyll to be measured separately from other pigments. Certainly MODIS will be able to make this measurement and perhaps SeaWiFS. Other accessory pigments, such as phycoerythrin, will require the increased spectral resolution of MODIS. One of the challenges remaining in bio-optical research is the use of full spectral measurements to separate all of the materials suspended and dissolved in the upper ocean. For example, can increased spectral resolution measurements be used to identify pigment groups within the phytoplankton, thus obtaining information on species composition? Can specific degradation products be identified? What minimal wavelength set is required to derive this information? There is evidence from laboratory studies and limited in situ research that this approach can be used to characterize the bio-optical properties of the ocean. By using inversion techniques, it should be possible to derive the bio-optical properties based on measurements of the complete spectrum of water-leaving radiance. The challenge for the next 10 years is to collect the necessary field data to strengthen the scientific underpinnings of this approach.

Such information on pigment groups are particularly important in studies of ocean carbon cycling. The patterns of cycling and vertical fluxes depend on the species structure of the phytoplankton community. Long-term changes in species composition in response to changes in atmospheric forcing is an important feedback in global climate change. Subtle shifts from one phytoplankton community to another can have dramatic impacts, yet we know little about large spatial scale changes in community structure. For example, the reduction of the ozone layer in the Southern Hemisphere results in increased ultraviolet radiation reaching the surface of the ocean. Preliminary studies indicate that the response to this increased UV is species-dependent; changes in species composition will likely ripple throughout the entire ecosystem.

Estimates of colored dissolved organic matter (CDOM) are also important in understanding carbon cycling. The amount of carbon in all DOM is thought to be as much as the entire terrestrial biomass. Processes that affect the partitioning of carbon between DOM and particulate forms will also impact carbon cycling.

Although improved estimates of phytoplankton biomass and perhaps the separation of biomass into contributions by major phytoplankton groups will be of great value, we must look beyond these static variables to measurements of dynamics, specifically primary productivity. Although several approaches to estimating primary productivity using remotely sensed data have been described over the last 10 years, it is obvious that our present understanding and data sets are not up to the task as yet. Most models rely on the basic biomass estimates collected from ocean color sensors to infer production rates. Various empirical methods are used to derive light adaptation and other physiological parameters to improve these rate estimates. Unfortunately, existing models explain less than 50% of the variance and the model predictions are only within about an order of magnitude of the actual values.

The challenge for remote sensing and biological oceanography is to understand the reasons

for these large discrepancies between actual productivity and predicted productivity. No doubt some of it results from the differing sampling characteristics of the satellite-based approach and the in situ measurements. That is, the satellite averages over depth and over area whereas ships sample discrete points. However, this cannot explain all of the variability. When we add some physiological information into the productivity models, the quality of the predictions increases substantially. Clearly, models based only on biomass are missing critical information. This is not a surprising result; the same results have been noted with terrestrial ecosystems. Although productivity is related to biomass, it is not the only determinant and it can give misleading results.

Much of the variability in the standing stock/productivity relationship is a result of physiological processes, either due to adaptation or changes in species composition. At present, we generally ignore species changes and use other variables to parameterize adaptation. For example, temperature may be used to infer nutrient availability (through mixing) as well as respiration. Presumably, we could use similar relationships involving sea surface temperature, wind stress, and latent and sensible heat fluxes to derive vertical mixing rates which could then be used to infer light and nutrient supply rates. Although such an approach explicitly includes processes that are only parameterized in simpler models, they are burdened with many other parameters that must be defined, such as adaptation rates.

In terms of ocean color studies, there are at least two lines of research. First, existing research indicates information on the photoadaptive state will significantly improve productivity estimates. Although the relationship of sun-stimulated fluorescence to photoadaptive parameters is not well-understood (especially for surface, light-inhibited populations), fluorescence bands will be included on MODIS and MERIS. This information will provide direct estimates of the physiological state of the phytoplankton and, coupled with biomass estimates using measurements from other wavelengths, will improve productivity models. The availability of morning and afternoon MODIS sensors will allow the study of some aspects of diel variability, at least in regions of the world ocean that are not obscured by glint during one of the passes. Measurement of diel variations in sunstimulated fluorescence might further improve models of phytoplankton growth rates. However, considerable field work remains before sun-stimulated fluorescence can become a standard tool for estimating productivity. The second line of research is to expand our models that incorporate more biological and physical processes explicitly. Clearly such an approach must reflect our increased understanding of the processes that regulate growth rates. A balance must be maintained between increasing the "realism" of the models and adding unnecessary detail. As noted earlier, realistic models increase the number of free parameters that must be estimated.

The net result of this research will be an improved understanding of the processes that control primary productivity. The availability of a multi-decade, consistent time series on ocean pigment and primary productivity will allow the scientific community to study the role of low frequency variability in ocean biology. For example, ENSO events occur roughly every 3-4 years so that a 20-year time series should contain about 5 such events. We should be able to characterize the impacts of ENSO events with a fair degree of statistical robustness. By using numerical models that assimilate observations from satellites and in situ sensors, we should be able to make predictions about the interactions between atmospheric forcing and primary productivity. However, data assimilation requires that we know the variance (error) structure of both the data sets being assimilation and the model relationships. For example, the temporal and spatial variance spectrum of light assimilation parameters would be a key component of a productivity model that relies on assimilation techniques. At present, our understanding of the time/space variability of most biological properties is quite crude. However, such measurements are not beyond the

scope of many planned and operational global oceanography programs. If our ultimate goal is the prediction of ocean carbon cycling in response to changes in atmospheric forcing, then we must begin to collect such data and develop such assimilation models.

The goal of a 20-year time series of global ocean color observations requires an unprecedented level of coordination between U.S. federal agencies and their international partners. Sensor design and calibration should be well-documented such that data processing can take sensor performance into account. Data systems must be designed so that the processing history can be preserved and data and algorithms can be easily shared. Yet such coordination must take place in an era of constrained financial resources. New methods for management must be explored.

The programmatic direction for current and planned work in ocean color remote sensing during the next decade is not very well focused. Several federal agencies, e.g. NAVY, NOAA, NSF, and NASA have interests in the ocean color research and applications in the U.S. Similarly, there is also strong international interest in Japan and Europe. NASA and NSF have taken the lead in national and international coordination through sponsorship of meetings, but there is currently no specific U.S. federal focal point for such activities nor any ad hoc or standing group which coordinates U.S. federal policy. Historically, NASA has taken the lead in this area, however there is no longer a civil service incumbent with this portfolio. A loose triumvirate of program managers is acting as an advisory group for the oceans with the biogeochemistry program manager taking the lead on ocean color matters. A diffuse federal focus coupled with a diffuse programmatic base in NASA has forced development of a variety of ad hoc efforts to deal with SeaWiFS calibration/validation, shiptime, etc. issues and has left the community with an unclear idea of which agency is responsible for which activities. The challenge is even greater in regards to foreign missions. In a cost-constrained environment, we must leverage all of the available resources where possible. For example, shared cruises could help reduce shiptime costs. Although SeaWiFS has extensive international involvement, there must be similar efforts focusing on the whole spectrum of ocean color missions.

The primary goal of a 20-year time series requires that the data processing and distribution system be designed to safeguard the raw data, the calibration and validation information, to enable reprocessing and to ensure efficient transfer of data and algorithms between many U.S. and international researchers. The data system cannot view itself in isolation from contemporaneous data centers or systems that may precede or follow it. High priority must be given towards ensuring compatibility of these basic services. While a data system may focus on a specific mission, e.g., SeaWiFS, its role in the larger constellation of ocean color missions must be retained.

Particular attention should be paid to retention of the design, calibration, and validation information. This will allow future researchers to reprocess the data in a consistent manner. Rather than becoming a standard product assembly line, the SeaWiFS data system should be able to locate and retrieve the raw satellite data and apply any algorithm. Interfaces should be clearly defined so that future advances in computer technology can be inserted. This requires a level of flexibility in the basic system design that is not usually found in most data systems.

The Ocean Color White Paper will conclude with specific recommendations that should be implemented to achieve the goal of a 20-year ocean color time series. The paper is presently under review by the MODIS Oceans team and will be distributed shortly to the SeaWiFS Science team.

Data Analysis and Interpretation

The previous semi-annual report contained the major findings from analysis of bio-optical data collected from a Lagrangian drifter. A manuscript has been prepared and will be submitted shortly.

Lagrangian drifters have been ordered from Metocean as part of an Office of Naval Research study of the California Current. These drifters will be equipped with a spectroradiometer that will measure upwelled radiance in the SeaWiFS channels as well as at 683 nm. The first deployment is scheduled for April 1994. Three more drifters will be deployed in June and three in August. Deployments will continue through fall and spring, 1994. There should be overlap between the drifter observations and the first part of the SeaWiFS mission.

Analysis plans are focusing on estimating Lagrangian decorrelation scales for upper ocean bio-optical properties and for comparing sun-stimulated fluorescence with primary productivity measurements.

Hiring of Information Systems Developer

We have completed two rounds of our search for an information systems developer. Although we have had several highly capable individuals apply for the position, all of them have accepted positions elsewhere. We have recently re-opened the search. Attached is a brief description of the position:

- Explore and prototype new methods of information and knowledge management in anticipation of petabyte sized Earth science data sets, advanced computer architectures, and distributed computation over high-speed networks

- Assist in developing consistent interface and processing strategy for Earth science data (including satellite data, in-situ data, derived and computer modelled data in a variety of formats, map projections, and with a wide variety of spatial and temporal properties)

- Evaluate existing information management packages and toolkits (such as object oriented databases)

- Manage and enhance existing relational database of satellite imagery

- Integrate satellite image database and relational database of in-situ ocean data

- Assist in developing links between visualization and analysis tools and database system

- Develop/enhance GUI front end for ocean database

- Assist with computer system administration and maintenance

Anticipated Future Actions

We will continue to review and comment on various MODIS sensor specifications plans. We expect that these activities will continue as costs become more constrained within the EOS program. Considerable attention will be placed on the definition of a "Standard Data Products" list which is being developed by the EOS Investigators Working Group.

With the start of the EOSDIS Core System contract, we will begin intensive interactions with the ECS contractor. Many of the present EOSDIS plans have been shrouded in secrecy during the ECS selection process. Various software and hardware development plans will need to be accelerated over the next few months in order to meet EOSDIS schedules. We perceive that these activities will consume much of our time.

In June, we will collect primary productivity measurements as part of ONR's study of the California Current. These data will be compared with the Lagrangian drifter data on sun-stimulated fluorescence. We plan to analyze these data in collaboration with Dr. Marlon Lewis. By the end of summer, we should have several months of bio-optical data from eight drifters.

With the upcoming launch of SeaWiFS, I will be participating in various science team and executive committee activities. There are many outstanding issues confronting the SeaWiFS project, and because the launch is now planned for October 1994, they must be addressed soon. In this regard, the Ocean Color White Paper will be completed and distributed this spring.

We will continue to work on our local SCF and the development of the MODIS Oceans team software development and data plan. This will include testing of new SeaWiFS atmospheric correction algorithms on the CM-5 at OSU. As soon as Dr. Howard Gordon has completed documentation, we will begin to port the code.

Lastly, we expect to hire the information systems developer this spring.

Problems and Solutions

The most serious problem facing this project is timely delivery of funding from NASA/GSFC. At present, funds have either been spent or obligated. Without an immediate transfer of funding from NASA/GSFC, further work must be delayed. OSU is becoming more conscious of delays in providing agreed-upon support by the federal government and is becoming more stringent in "advancing" the funds. If it becomes necessary to lay off personnel because of further funding delays, this work will be in serious jeopardy. This problem has been brought to the attention of both EOS Project and Program management.

Further, additional responsibilities for SeaWiFS have been levied on various MODIS Oceans team members (including myself). While I fully support these tasks, we must work with both EOS Program and Project management to assign priorities to these various tasks. We expect that funding will continue to be more constrained; somehow we must focus our limited financial and time resources on those tasks that are most important. I urge a meeting of the appropriate management staff as soon as possible.